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CONVECTIVE RAIN IN THE PEP MODEL

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One of the generally recognized failings of the PEP forecast model has long been its inability to predict (or even suggest) the presence of convective-type rain, particularly in summertime air mass type situations. The difficulty can be partially attributed to scale and partly to physics. The scale problem is obvious -- the spacing of the forecast grid points is too large to capture even groups or clusters of convective storms, let alone individual cumulus showers. The physics problem is more subtle but presumably has to do with the non-hydrostatic dynamics of cumulus clouds and their interaction with their environment -- topics that are matters of active research and sufficiently unresolved in their details to be ready for inclusion in an operational forecast model.

However, we must not despair. The following considerations have lead to an effort at parameterization of the presence of convective rain in terms of the relative stability of the forecast temperatures and precipitable water amounts. If we consider that a single gridpoint represents some sort of an average of the forecast conditions over a considerable area (the area of a grid square), it seems a reasonable assertion that if the conditions at that point are, say, conditionally unstable, somewhere within that area that instability should be released. There might be an area of intense local heating or some sort of local convergence sufficiently strong to set off the convection and it would rain, even though the forecast humidity was not at saturation. This, then, is the basis of the parameterization.

This basis, however, says nothing about *how much* rain falls in these conditions of conditional instability -- this requires additional parameterization. Here the assertion is that the quantity of rain is proportional to the degree of instability. The numerical amount actually computed will be seen as a consequence of the detailed procedure described below.

Detailed Procedure

At each time step, at each gridpoint, and in each of the three moisture bearing layers, this sequence of operations and tests takes place:

1. The relative humidity is tested: if the humidity is less than 75% or is 100% (saturated), the remainder of the conditional instability tests are bypassed; if the humidity is between 75% and 99% (inclusive), then the temperature and moisture content of the layer are taken to define a parcel which is then lifted (by the usual "parcel method") to the pressure of the center of the layer immediately above.

2. The temperature of the lifted parcel is compared with that of the layer up to which it has been lifted. If the lifted temperature is colder than the layer, further consideration ceases as this is a stable situation. If, however, it is warmer (the equivalent of a negative lifted index), we continue with the next two steps.

3. The amount of rain assumed to fall from the unstable situation is computed by calculating the amount of energy that would be required to warm the entire upper layer by the number of degrees that the lifted parcel is warmer than the upper layer. This quantity of energy is then used to calculate the amount of condensation that would be necessary to create that energy, via latent heat, and the appropriate amount of water is allowed to accumulate at that grid point. This rain falls undisturbed through any intervening layers and there is *no* latent energy actually added to the model in this entire process. Since this is a highly parameterized process, it seems risky to change the dynamics of the model by actually introducing the latent heat energy into the temperature forecast. At this point, the forecast is totally unchanged (except for the quantitative precipitation itself), we have only added a numerical interpretation of some of the results. It is necessary, however, to alter the forecast slightly, thus:

4. After the amount of convective rain has been computed, the two (unstable) layers involved are mixed in the vertical to a state of neutral conditional instability -- the upper is warmed slightly and the lower layer cooled, both by an amount equal to approximately half the parcel - layer temperature difference. This has the effect of preventing an excess of rain from falling at the same spot time after time and serves to stabilize the model in a manner not inconsistent with that which happens in the atmosphere. This mixing procedure can, and does, change the rest of the forecast but in the tests we have run, such changes are quite insignificant -- ten meters or less at 500 mb and a millibar or less at sea level, and these only at and in the neighborhood of the actual points taking place in the mixing.

5. This entire procedure is repeated for each layer in the vertical and iterated until all the conditional instability (and associated rain) that is available is released.

Results from Test Cases

Perhaps about the most efficient way to present the results is in tabular form, giving the standard precipitation forecast scoring methods for the operational and the corresponding convective 36 hour forecasts. All scores are for the rain/no rain forecast, and are for the NMC 60 city scoring network.

		F	O	H	Threat	Post.	Pref.	Bias
12Z	OPNL	2	8	1	.11	.50	.12	.25
4 Jun 71	TEST	8	8	2	.14	.25	.25	1.00
12Z	OPNL	3	9	1	.09	.33	.11	.33
13 Jun 71	TEST	12	9	5	.31	.42	.55	1.34
00Z	OPNL	4	11	0	0	0	0	.36
20 Jun 71	TEST	8	11	2	.13	.25	.18	.73
12Z	OPNL	0	14	0	0	0	0	0
27 Jun 71	TEST	7	14	1	.05	.14	.07	.5

Although four test cases cannot lead one to complete assurance, we can note that the change lead to an improvement in all (save one or two) of the verification scores in all the cases. Also, subjection evaluations of the forecasts indicated that even in those areas where the forecasts did not verify exactly (or where there were no verification stations) the new wetter program did provide more useful guidance than the current system.

Impact on NMC Forecasts

Judging from the test cases, such alterations in the sea-level pressure and upper level height forecasts as may be caused by the change will be completely indetectable.

There are a couple of areas where the impact may be more substantial. One is in the quantitative precipitation forecast itself of course - it's wetter - to some extent there is more rain in locations where there was some previously, and to a greater extent there are more rainy gridpoints than before.

The other area of possible impact would be in the lifted index and similar such measures of vertical stability derived from the forecast temperatures. The vertical mixing of conditionally unstable points will cause a stabilization of the forecast atmosphere which will be reflected in the lifted index. To the extent that the lifted index has been used in the past as an indicator of possible precipitation areas, this stabilization should cause no difficulty as the precipitation will now be explicitly forecast by the model instead of the implicit stability derived "forecast." For those not having access to the grid point by gridpoint QPF information, a study of the FOUS transmissions should indicate the degree of effect to be anticipated.